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GEOLOGY AND ECONOMICS[1]

DURING the century which has just closed, the various branches of natural science, botany, zoology, geology and their relatives, having earlier completed their childhood, attained to the well-rounded development of maturity. Their broad truths were given clear expression; they were widely apprehended; and they became the foundations of various inventions and applications of far-reaching influence upon human welfare. Geology, although closely bound up with agriculture, has, nevertheless, been especially concerned with mining. And justly so, because its contributions to the art of mining have been no more than a filial return, since mining as practised in the middle ages was the parent of geology. Until recent years geology's services to the industry have been chiefly rendered in spreading sound and reasonable ideas regarding the nature and distribution of the useful minerals; in solving the perplexing structural questions affecting their occurrence, and in facilitating the discovery of new fields.

The problems of the production of the metals and non-metalliferous substances, as we know them to-day, are of quite recent growth. High explosives, efficient engines and pumps, steam shovels and the like are all not so old as many men who are still living. They have so greatly reduced costs that practically a new world has opened to the miner. Not only on the surface or near it has he been able to work, but the depths have become accessible, and where the value of the ore justified the ef-

[1] Presidential address before the New York Academy of Sciences, December 19, 1910.

fort, no floods of water have sufficed to keep him out.

These successes coupled with ever-expanding markets have until recently directed attention almost wholly toward discovery and production. But the last ten years have brought a further change. We are now less concerned about new discoveries than about the maintenance of old ones. We are not altogether intent on production, but are much given to forecasting and husbanding. From being solely an aid to the miner, the active worker, the producer, geology has become the colleague and helper of the economist, the statistician and the philosopher.

Like all other changes in fundamental points of view, this one has not come with absolute suddenness. As far back as 1879 certain geologists and engineers began to raise and discuss the question of the duration of the Pennsylvania anthracite. In 1894 the late Richard P. Rothwell, long the able editor of the *Engineering and Mining Journal,* gave these coal fields a future of 70–100 years. Thus for over thirty years the question of their death has been a very live one. Even earlier the future of the coal-fields of Great Britain came up for discussion. A parliamentary commission was appointed in 1866 and reported upon the question in 1871. For forty years anxiety has prevailed regarding the continued production of our petroleum wells, and naturally so. The very means of production of this useful source of heat and light starts a train of thought along the lines of its permanence.

Some ten years ago, the question of our reserves in iron ore began to excite interest. Mr. Andrew Carnegie gave most forcible expression to the feeling of alarm in his rectorial address in 1902, at the University of St. Andrews, Scotland. Mr. Carnegie was known from one end of the world to the other as one of our greatest iron-masters and his words made a profound impression. In his address he assigned us only enough first-class ore to last for sixty or seventy years, and only enough of the inferior grades for thirty years thereafter. We all trembled for some years with the prospect of seeing our greatest industry in the production of metal, disappearing within a century. Many thoughtful people began to wonder what would become of us with its extinction.

I have thought, therefore, that it might be not without interest if we take up this evening the more important of our metals and pass in review some of the fundamental facts of their production, the yield of their ores, the foreign sources, the future probabilities and the effect upon the civilization of our own and other lands which would result from their curtailment. In a word, we may for a time discuss geology and economics.

The iron industry in the United States took its rise in the colonies along the Atlantic seaboard—and at the outset was based upon the magnetic ores and brown hematites there occurring. For one hundred and fifty years its growth was slow. In the decade of the forties and fifties of the past century it had spread to the Adirondacks and in the fifties began its development in the Lake Superior region. Not until after the close of the civil war and the resumption of peaceful activities did this great industry manifest its possibilities. With improved facilities of navigation which placed Lake Superior in easy communication with the coal-producing states of Pennsylvania and Ohio, the iron-ore-producing states of Michigan, Wisconsin, and later Minnesota, came rapidly into prominence. In somewhat slower growth Alabama, during the seventies and eighties gathered headway. At present four fifths

of our ore supply comes from the three Lake Superior states, and three out of the four fifths from Minnesota alone. Alabama, Tennessee and Georgia together yield one tenth and the remaining tenth is divided among a dozen or more other states, of which New York is the leader. Since 1880 the total has increased about sevenfold and Pennsylvania, then the source of about one quarter the supply, now yields approximately one and one half per cent. Minnesota, now the great source of ore, only entered the lists in 1884, and only began to utilize its present great mines about ten years later.

Thus in the brief course of thirty years there have been very great rearrangements not only in geographical sources of supply, but still more in actual amount of output. In normal, prosperous years the annual production is somewhat more than fifty million tons of ore.

But there have also been other changes not less striking. In early days and in remote situations only the richest ores could be mined. Magnetites for example in the lump from the Adirondacks afforded over 60 per cent. metallic iron. Specular hematites from the Lake Superior districts necessarily yielded 65. For some years no one regarded them with respect if they contained less. Red hematites from Alabama afforded forty-five to fifty. The minor ores near the furnaces were often much lower —but they may be passed over for the moment in emphasizing the larger features. Magnetites in the Adirondacks are now concentrated before shipping and in instances two and one half to three tons are condensed to one of 65 per cent. tenure. The crude ore carries 33–35 per cent. During the early years of the present decade the general average yield of Lake Superior shipments fell off about one per cent. per year—so that now the soft ores, so called in contrast with the hard lump specular of earlier days, range somewhat above 50 per cent. Alabama ores, once 45 to 50, now are very uniform at 36 to 37. So far as the brown hematites are concerned, which in the form of lumps, crusts, pipes, etc., are distributed throughout ochres and clays, the percentage of available iron in the crude ore is lowest of all. We wash from eight to ten tons of crude in order to get one ton of concentrates of say 40–45 per cent. in iron, and under favorable circumstances may treat much lower raw materials. Soft magnetites in Pennsylvania, which on the richer outcrops gave 45 to 50 per cent., are now dug in very large amounts with a yield of 43. If we take the total production of ore in the United States and the total production of pig iron, we find the yield in the large way to be about 50 per cent.

In order to gain some idea of the comparative merits of these figures when set alongside the percentages in the ores produced in other lands, a few cases may be cited. Germany in 1907 produced 27,700,000 tons of ore, exported nearly four millions and imported eight and one half millions. Of the local production three quarters were obtained from Elsass, Lothringen and Luxemburg, whose percentage in iron ranges between 30 and 40 and is on the whole not very different from Alabama's present percentages of 36–37. Germany's imports, of course, range much above these figures, else the ore could not stand the freight charges from mines in such remote countries as Sweden, Spain and Algiers.

Great Britain produced in 1907, approximately, 15,000,000 tons, of which about three quarters were the so-called impure carbonates yielding 30–35 per cent. iron. One ninth of the total was red hematite at 50–55. The general average would be somewhat less than that of Alabama. Im-

portations of richer ores, especially from Spain, helped to raise the furnace yield.

France in 1908 produced 10,087,000 tons, of which 88 per cent. was mined in French Lorraine of the same type as the main German supplies. The ore ranged from 33 to 40 per cent.—again not far from the Clinton ores of Alabama. We are justified, therefore, in saying that the largest part of the output of the next three producing countries of the world is about the same as the lowest grade of lump ore, which can be profitably mined under present conditions in the United States. When, therefore, we come to estimate comparative reserves we must realize that in the Lake Superior region—our greatest producer—we pay no attention to-day to ores, which are, nevertheless, much richer than those of Great Britain and continental Europe.

In the opening sentences I spoke of the anxiety which was felt a few years ago regarding the reserves upon which the industry would of necessity rely for its future. I mentioned Mr. Carnegie's remarks in 1902 at the University of St. Andrews. But he was not the only one who discussed this question and now in referring to one or two other forecasts, I think you will have in mind some of the fundamentals which establish a correct point of view.

In 1905 Professor Törnebohm, the eminent and greatly esteemed former director of the Geological Survey of Sweden, assigned to us a reserve of only one billion and sixty millions of tons. Obviously, at an annual production of over fifty millions this reserve would only last twenty years. The future thus looked still darker than when seen through Mr. Carnegie's spectacles. Much opposition arose at once, however, to Professor Törnebohm's data, because from them had been omitted the red hematites of Alabama, which can be very accurately estimated and which of themselves are thought by competent observers to have a half billion tons for the future. Additional modifications must also be introduced when we properly appreciate the downward tendency of workable percentages. The lower the percentage of iron which we require in the product of our mines, the greater the amount of ore which at once becomes available. This is peculiarly true of iron, because of its very wide, general distribution.

In 1907 in anticipation of the International Geological Congress of 1910, which was to be held in Stockholm, the Swedish committee of arrangements began the preparation of a series of estimates of iron reserves in all the countries of the globe. Geologists familiar with local conditions were requested to prepare the figures each for his own country. It fell to the speaker to start the collection of American estimates and much aid was afforded by several of the largest companies owning reserves. Shortly thereafter, however, the interest in the conservation of natural resources sprang up and Dr. C. W. Hayes, of the United States Geological Survey, was empowered to use all the resources of this great organization in assembling data on iron. In this way figures as reliable as can be expected are now available. We learn from them that we may consider three and one half billion tons of fifty per cent. ore as assured in the Lake Superior region. Of this great total three billions, one hundred millions are in the Mesabi range of Minnesota. At thirty millions of tons per annum, the present output of Minnesota, we have a reserve for a century.

On the other hand, if we drop to 40 per cent. or slightly below, still, however, remaining a few per cent. above the Alabama grade, the drill holes show above depths no

greater than those already reached in some mines, two or three hundred billions of tons of siliceous hematites, giving amounts practically inexhaustible.

In the Alabama ore beds we feel assured of five to six hundred million tons of the grades now utilized and there may well be twice that number. The conservative estimate would afford enough to last at the present output of that state longer than a century. In addition there is much reason for thinking that there may be two or three times as much.

Speaking for the country as a whole, we may say that there is an assured and demonstrated supply, at present rate of output and at present percentage of yield, for about a century. There is, furthermore, a less accurately measured but still very probable addition, when we allow for lower grade but still practicable ores, which will be sufficient to last at present rate of production for fifteen hundred years to come.

If, however, production increases, as indeed it may with a rapidly growing population, and if in this way heavier and heavier drafts are made upon even this great reserve, where shall we look for more? There may be some new discoveries within the United States, but at present it is impossible to speak definitely of them. We may ask if there are other supplies in neighboring lands. To this question we may answer yes. Along the north shore of Cuba, toward its eastern end and near the sea, three areas of what formerly appeared to be a barren, ferruginous soil have been discovered and tested, so that we now know that there are two to three billions of tons of a very pure iron ore, which, when deprived of the large percentage of water which it contains—a cheap and simple process—will yield from 40–45 per cent. iron. This variety of ore already begins to enter our ports and the deposits will undoubtedly contribute in no unimportant way to the output of our furnaces.

The report of the International Geological Congress has shown further that in Newfoundland there are quite probably more than three billions of tons of red hematite, whose present yield averages 54 per cent. From Brazil, moreover, in the state of Minas Geraes, but pretty well back from the coast and not yet opened up by rail, as estimated by Dr. O. A. Derby, there are from five to six billion tons of 50–70 per cent. ore awaiting the drill and the steam shovel. Ore from Brazil faces a long sea voyage, but the grade is rich and the iron masters of this and other countries are looking upon these deposits as well within the possibilities of the future. Ocean freights are kept at very reasonable rates in later days and once on a steamship even so low-priced a commodity as iron ore, if of good percentages and cheaply mined, can be taken relatively great distances. This is demonstrated by the shipment this year from the mines of Kiruna, 112 miles within the Polar Circle in Lapland, of 300,000 tons of ore, 113 miles to the Norwegian coast by rail, and over 4,000 miles to Philadelphia by sea, with no great prospect of a return cargo. These shipments also demonstrate that we are not without the range to which European ores may be shipped when exceptionally rich. Some portion of the vast ore body of Kiruna, with its demonstrated 500 millions of tons of 65–69 per cent. ore will also reach American furnaces.

But even were our actual ores of present grade to become exhausted, iron as a metal would not fail. The basic rocks with their low percentages still remain. The trap-rock of the Palisades contains 7–8 per cent. of metallic iron, a value that is far above the general yield of our copper ores in the red metal.

Iron, therefore, will never fail. It will probably not change in its general relations to modern conditions for a very long time to come, so far as its ores are concerned. We may have greater anxiety about the supplies of coking coals than about the iron ore, but there are always such possibilities of improvements or changes in processes that no one can justly give way to unqualified forebodings.

Copper is the metal generally considered next in importance to iron. It is a very old one in the history of the race. The bronze age, you will recall, preceded the iron age. Prehistoric man in Europe solved the mixed metallurgy of copper and tin before he learned the smelting of iron. Prehistoric man in America found native copper on the shores of Lake Superior and passed it in trade a thousand miles from its home. As a cherished possession it constituted his ornaments while he lived and it was buried with him after he had died.

Among the moderns, copper is most extensively employed in brass, but as a conductor of electricity it finds year by year increasing applications in the purest condition in which the metallurgist can supply it. If at home or in your office you look around your chair or desk you will be surprised to find how universally employed it is.

Greatly stimulated by the development of electricity in later years the production of copper has advanced by leaps and bounds. At present the United States are the heaviest producers, with Spain following next, but only yielding one eighth as much. The United States furnish over half the total. In 1850 the United States yielded 728 tons; in 1900 over 303,000 and in 1908, 471,000. Meantime in 1850 the price of copper was about 30 cents per pound. Its lowest point in recent years was nine cents in 1894. Its highest, 25 cents, was attained in 1907. We may each of us imagine the variation in the profits of a mining enterprise as between 11 cents a pound and 15 cents, let alone 20 or 25 cents. Mining costs, smelting and freight charges, show no such variation, so that with rising prices profits greatly increase. Indeed, few of the metals have such extraordinary ups and downs as does copper.

In its ores the yield varies greatly. On Lake Superior, where the native metal is distributed through ancient lava flows in little pellets, leaves and sheets, it has been profitably mined and produced through periods of years, when it constituted but three quarters of one per cent. of the ore. The general run is, however, one per cent. and above. If we recall that in a ton of 2,000 pounds one per cent. is 20 pounds, and three quarters of one per cent. 15 pounds, and if copper is selling at, say, 13 cents, the mining manager must break down, hoist, concentrate with attendant losses, and smelt an ore worth less than two dollars for all the metallic contents which it contains. We can thus gain an idea of the close and economical work required and the ability demanded of a manager. As the price rises the profits greatly increase, and temporarily idle mines are brought within the widening remunerative zone, and are quickened into life. As the price falls, the mines dangerously near the line close down and production ceases. The lowest cost of production claimed is from the low grade and very large ore bodies of the west and is placed at or about eight to nine cents per pound laid down in New York.

In copper ores outside of the Lake Superior region, we usually find the metal in composition with sulphur. The ores as they come from the mine may be rich enough to go directly to the smelter, or they may require concentration before the

grade is sufficiently high. The ores which are directly smelted reach the minimum of copper in the Boundary district of British Columbia, but associated gold and silver raise the value per ton above four dollars. Copper ores yielding copper alone were smelted at Ducktown, Tenn., during long campaigns at a little less than 2.5 per cent. In earlier years and in many mining districts ores as high as 20 per cent. were found, rarely even higher, but they in time were exhausted and five per cent. would be quite rich for day in and day out averages.

These statements will serve to establish a point of view and likewise afford a standard of comparison. What is the outlook for the future of copper production?

We can not predict copper with the certainty of iron. It seldom appears in bedded deposits which can be measured. In the deep mines we can not always see ahead for more than a year or two. In some mines we know from exceptionally complete development, of twenty years' supply. But the great advance in copper mining has been the entrance of relatively low-grade ores into the productive field. The wall rocks of ten years ago have become the ores of to-day. Where we find in porphyries or schists copper sulphide disseminated in fine particles or as coatings along crevices, and in sufficient richness to yield two to two and one half per cent., throughout very large bodies, it can be mined very cheaply and concentrated in enormous quantities so as to return a safe margin. If the ore lies near the surface, steam shovels make excavation extremely low in cost. The huge pits and open cuts of this type of mine in the west are now among the great sights for the traveler. Mills whose insatiable crushers take as much as eight or ten thousand tons per day are no longer unknown. The drill blocks out the ore long before mining begins, and reserves can be estimated more closely than in the vein mines.

If a mine is called upon to furnish a mill with 2,000 tons per day and we allow 300 working days in the year, 600,000 tons must be supplied per annum. For a life of twenty years, a time practically demanded of such an enterprise to justify the great expense of installation, at least 12,000,000 tons must be shown by the drill before the enterprise can safely begin. If we expect to mine three times this amount per day we call for three times as much ore. These figures, large as they may seem, are not beyond the estimates of ore bodies as now blocked out in several places in the west, and even with these great demands, twenty years supply and even more in instances have been demonstrated.

Let us now imagine again a 2,000-ton daily output of say 2.25 per cent. ore, of which the mill saves two thirds, or 30 pounds of copper in the ton. The output in copper per day will be 60,000 pounds, or 30 tons and for the year 9,000 tons. Should three new companies start up with four or five times this output, 36,000 to 45,000 tons will be added to a yearly supply, which in 1909 was 552,668 tons. We see great need of a growing demand in order that these vast contributions may be absorbed. Yet I have made no unreasonable assumptions nor have I overstepped the practical certainties of the next few years.

How long will our copper hold out? Mines come and go, and for the immediate future there will certainly be no scarcity. Copper does not oxidize as readily as iron and is not lost. The world's stock steadily accumulates. But twenty years is not a long look ahead. Are there new countries which will be producers? Some of the old mines in Europe are now no longer great sources of the metal.

We do know of possibilities in Alaska that will add some contributions. We know of new or recently opened ore bodies in Peru, Bolivia and Chile that promise well. We hear of very large deposits in the southeastern corner of the Congo State, once worked by the ancients, now revived by the moderns and possessing large reserves of 15 per cent. copper ore. The Cape to Cairo railway will give them great impetus. For the immediate future there is no lack, but if we look fifty years or a century ahead we can speak with less confidence. In a general way we may say that probably new discoveries will, for a time at least, more than keep pace with demands. But when we look fifty years into the future we are not so certain. It behooves the producers to use no treatment of an ore except a careful and economical one. If tailings and waste from our mills now contain one third the copper in the original ore, they should be impounded and kept from being washed away by floods, against the possible call of the future. We dare not say that they will never be within the ranges of profitable treatment even though their low percentage places the copper beyond reach to-day. The copper situation is not one to excite anxiety, yet it is also one not to encourage extravagance.

Following copper we may take up lead and zinc, which are the next metals in amount of production. Of the three, zinc is the least in total tons and in total value. We may gain some idea of the relations from the small table given below in which zinc is taken as unity and the figures relate to 1908.

	Amount	Value	Price per Pound
Zinc	1.0	1.0	1.0
Lead	1.6	1.45	0.9
Copper	2.46	7.0	2.8

Thus we see that the lead production is one and three fifths that of zinc, and the copper is two and one half times; that the lead is about one and one half times the value of the zinc, and the copper is seven times; and that zinc is worth more per pound than lead and only about one third as much as copper. The red metal is not only produced in greater amount, but is worth more per pound and in the aggregate than both the others taken together.

Among the nations of the world the United States has become the chief contributor of lead and yields year by year proportions varying from 27 to 33 per cent. of the total. The next country is Spain with about two thirds as much, and Germany follows with three fifths.

In this country the state of Missouri is the heaviest contributor and is responsible for practically 40 per cent. of the total. Idaho is next with about 32 per cent. and Utah follows with 13 to 14. The western lead all carries silver. The precious metal is an important factor in the value of the product. When we come to forecast the future it is not possible to see more than a few years in advance or to speak in more than a general way. The miners would be glad to be assured of reserves of ore for a goodly period of years, but it is seldom possible or practicable to demonstrate their presence. Operations necessarily continue with a few years' supply blocked out in advance of the actual mining and the hope is maintained that more will be found. Very often the expectations prove justified. We may therefore in a measure forecast future experience somewhat by the past. In the Missouri lead region mines have been operated for forty or fifty years, not on so large a scale at the outset as now, but continuously. For some years at least no change may be anticipated. In Idaho the lead ores are now known to continue to

depths of nearly 2,000 feet beneath the overlying surface and to be holding out without essential change in character. In Missouri, however, the mines never have been very deep, that is over three or four hundred feet, and the compensation comes in wide horizontal extent.

Some of the old time heavy producers have greatly declined. Nevada, once an extremely important source of lead, is now a comparatively small contributor. Colorado, in former years our chief source, has dropped to only a third of its one-time yield, and yet the total of the country has gone quite steadily on. The fall in the price of silver was a hard blow to the western lead miners and naturally not only cut off their profits, but raised the necessary percentage of metal in the ore.

If we look ahead for a century or some such long period, we may not feel assured that production can be maintained at present rates. There may, of course, be new discoveries in lands not as yet fully explored. Being distant from present centers of consumption as they necessarily would be, their entry into the markets would imply higher prices so as to meet the charges of freight.

On the other hand, lead is a metal which oxidizes or changes very slowly. In its applications in the metallic state it tends thus to accumulate unless lost in use, as in the case of shot and bullets. It is extensively employed in the manufacture of paint and in this form is of course never recovered. About two per cent. of the entire output is destroyed to give us white and red pigments.

It behooves us on the whole to be careful in the use of lead and to avoid, when possible, its unnecessary sacrifice.

Zinc is a metal of comparatively late introduction into commerce in the large way. Although known for centuries, it has found its chief applications in the last sixty years. There was no zinc mine in the United States until approximately the year 1850, and from the Missouri region whence we now obtain our chief supplies, the really serious contributions began about 1870. Lead, indeed, was mined and prized long before this, but the associated zinc ore was thrown one side on the dumps. In the west the same experience continued until much later. Zinc was a nuisance in the metallurgical treatment of lead and even the lead was sought and smelted either because of its own silver contents or because it made possible the treatment of other refractory silver ores. In the metallurgical work the zinc was volatilized or slagged off and was lost. Indeed, one of our most serious metallurgical problems has been the successful treatment of lead-zinc ores and many investigators have addressed themselves to its solution. Now that anxiety is beginning to manifest itself regarding zinc supplies for the future, the desire to save it is stronger than ever.

Zinc, however, is a peculiar metal and because of the exigencies of its treatment its ores must possess greater richness and greater purity than those of other base metals. Thus in the case of copper a ten per cent. ore is in later days phenomenally rich, and as it can be smelted in a shaft furnace the presence of iron or lime or other bases that make fusible slags is an advantage. But zinc ores, perhaps after preliminary roasting, must be reduced and the metal must be volatilized at a high temperature from a small charge in a retort. The presence of fusible bases destroys the retort and the bases are therefore debarred beyond certain small percentages. Thus it happens that a forty or fifty per cent. zinc ore might be valueless if contaminated by iron or lime beyond a narrow margin. While almost any con-

ceivable mineralogical aggregate that contained ten per cent. of copper would be a very valuable ore, a zinc-bearing aggregate with four or five times as much zinc might be unsalable.

Suppose we compare them from another standpoint. Copper ores, if at all profitable, are worth about so much per unit of copper, that is, so much for each per cent. While there is some variation yet the contrasts as among three per cent., five per cent. and ten per cent. ores are much the same as the ratio of the per cents to each other. But if we think of a zincblende ore or concentrate of 60 per cent. as the standard of richness, a fifty per cent. ore is not worth five sixths as much, nor a forty per cent. ore two thirds. On the contrary a forty per cent. ore might be entirely unsalable. As the zinc decreases other deleterious bases take its place and a worthless mixture soon results. Zinc is in many ways the most peculiar of the metals and when we come to deal with its profitable treatment analogies with other metals fail.

In 1907 the United States were the chief producer of zinc among the nations, but, as a rule, Germany leads, followed by this country and Belgium in the order named. In later years our output has varied from 26 to 30 per cent. of the total. As a rule Germany is 2–4 per cent. in excess of us and Belgium is 4–5 per cent. less.

In America, Missouri is the chief source of zinc. Its production from the mines was in 1908, approximately one half the output of the entire United States. New Jersey follows with somewhat over one quarter the total, while all the rest are much smaller.

The Missouri ores as thus far produced have been obtained from comparatively shallow depths. They extend lengthwise and sometimes laterally to greater dimensions than vertically. While it is not beyond the possibilities that lower lying deposits may be discovered, since zinc ores are found in Arkansas in strata of lower geological position, anticipations of this reserve have not as yet been demonstrated on a large scale. Kansas, Oklahoma and Arkansas, the states neighboring to southwest Missouri, also have some zinc ores, but they are not of great importance; southwestern Wisconsin is a very old mining district and has many small mines, which were earlier worked for lead. They have been revived for zinc in later years and are now an appreciable but not great factor. They may develop somewhat more extensively and may last for a goodly series of years, but the mines are relatively small and are wet, so that exploration does not go very far in advance of mining.

In New Jersey the future is best forecast of all. For thirty or forty years there is no occasion of anxiety. Yet thirty or forty years pass quickly and then we must prepare to look for other sources. To make the zinc blende of the Rocky Mountain region available, an increase in price is practically necessary, otherwise the metal can not stand the freight charges. There is zinc ore in the west but to what extent we can not well say. It has been avoided rather than sought in most of our mines. Yet we do note symptoms of attention to it. In Butte, Montana, efforts are being made to concentrate it. Shipments of oxidized ores have been made from New Mexico for some years past. Until recently large amounts of peculiar appearance seem to have been overlooked at Leadville, Colorado. They promise to be an important resource. A government commission has reported upon the occurrence of the metal in British Columbia in the hopes of utilizing the ores. From Mexico, too, we learn of explorations for zinc. Conditions are changing in the case of this metal and

more and more it is certain to be brought from remoter localities. But when we look a long way ahead, say for a century, we can not feel free from anxiety. This condition of mind is even more prominent in Europe than in America. The waning of the famous old mines near Aix la Chappelle, and the apprehensions felt regarding other sources, have led to a world-wide search. Zinc ores, for example, now reach Hamburg from the Pacific shore of Siberia, and as other discoveries are made, additional points remote from present smelting centers are likely to be shippers, provided that transportation is by water. Nevertheless, all these new conditions call for advances in price and before many years zinc bids fair to take the upward course.

The precious metals, silver and gold, are the only other two which we may pass in quick review. Silver is a less profitable object of mining than it was twenty years ago, and yet with the improvement of processes of extraction and with the great development of the output of copper and lead in which it is a by-product, the fall in its price of the early nineties has been less disastrous to the amount produced than one might have supposed. Our maximum output was reached in 1892 when it was 63,500,000 ounces valued at $55,662,500. In the same year about 1,600,000 ounces of gold were produced valued at somewhat over thirty-three millions of dollars. In 1908 we are credited with approximately fifty-two and a half million ounces of silver, valued at twenty-eight million dollars. Gold, meantime, with the fall of silver, has advanced to 4,574,340 ounces, valued at $94,560,000.

In the United States we have now comparatively few distinctively silver mines. Among them Tonapah, Nev., has been chief. Mexico is the particular home of silver, but the remarkable district of Cobalt, Ontario, has given great present importance to Canada. In our own country we must expect the white metal to share the fortunes of the copper and lead with which it is chiefly produced. As influencing its future, copper is a more serious factor than lead, both for the reason that Missouri lead contains little if any silver, and because western copper ores display greater reserves than do western lead ores. As sources of silver there were in 1908 no very great differences among Montana (a copper-silver state), Colorado (a silver and lead-silver state), and Nevada (a silver state). Utah (both a lead-silver and a copper-silver state) afforded about five sixths Montana's output; and Idaho (a lead-silver state) about three fourths Montana's;[2] Arizona (a copper-silver state) follows after a long interval, and the others are much smaller.

As an indication of relative magnitudes, while the output of the United States was placed at 52.5 million ounces in 1908, Mexico afforded 72.6 and Canada 22 millions. Australia with 17.3 follows and then Peru with 7.2 millions. A metal with so high a value as silver will stand transportation from remote points, and although the production in one country or another may fluctuate, the world's supplies are not likely to be seriously affected for many years. Silver is largely used in the metallic state, and, being resistant to change, it tends to accumulate. Photography is the most destructive industry to it, and when once employed in this art, it is practically lost.

[2] In ounces they range:

Montana	10,356,200
Colorado	10,150,200
Nevada	9,508,500
Utah	8,451,300
Idaho	7,558,300
Arizona	2,900,000

Gold is mined for itself alone to a far greater degree than is silver. Thus in this country in 1908, almost 93 per cent. of the gold was produced without regard to other metals and only 7 per cent. was obtained with copper and lead: whereas about 60 per cent. of the silver was produced in association with the base metals. Gold in later years has increased in amount of production beyond all previous experience. The steady and scientific digging and washing of low-grade gravels are, in the long run, more productive than the rich skimmings of the early California, Australia and Klondike placers. The world's total of 444 millions of dollars in 1908 was in excess of any previous year. The Transvaal furnished the most, nearly 146 millions. The United States followed with 96 millions; Australasia yielded 72.5; Russia nearly 40; Mexico, 24.5; Rhodesia, 12.2 and British India, 10.4. All the rest were under 10. The countries mentioned supply about 90 per cent. of the total.

In the United States 28 per cent. of the gold comes from gravels and these are the least permanent of the sources of the metal. With their exhaustion the output will decline. In the deep mines there are signs of waning output in some districts. In our own country new districts have come to the front from time to time to give on the whole a steady increase in output for forty years past. So far as the future is concerned, however, the ups and downs of any one or of several countries make slight difference in the world at large. Gold can be readily shipped from point to point and the place of its production is a comparatively small matter.

Like silver and to an even greater degree it resists chemical change, so that the world's stock constantly augments. No very important portion is permanently lost in the arts.

Gold and silver are so extensively employed in coinage that they have received more attention at the hands of economists than have any other metals. Gold in later years, with its increasing production has led to much philosophical speculation. The establishment of it as the monetary standard and the elimination of silver from this position have occasioned some of the most heated political controversies in the history of our country. Into these a geologist is not competent to enter. We all probably realize from old-time experience how easy it is to become befogged. But the geologist can say that for some years to come the gold production will undoubtedly be maintained. And that while the Klondike and Alaska may wane, Siberia will increase.

We may now briefly summarize the main facts affecting the six metals which have been passed in review. It will then be possible to draw some general conclusions. Of iron ore there is no lack, nor need any one be apprehensive regarding the supply of this metal, but before very many years have passed the yield of the ore will have decidedly declined. While the falling off will be gradual, it will undoubtedly tend in the long run toward forty per cent. This change is in itself important because, unless otherwise neutralized it will raise the cost of production. It makes necessary the melting of more barren materials in the furnace, so that the consumption of fuel rises with respect to the amount of iron produced. It means also the mining and freighting of an additional burden which yields no return. From whatever point of view we regard it, other things being equal, the cost of production rises. The great reserves of lower grade ore than at present mined are in the Lake Superior district. They are siliceous ores, and will require in smelting the admixture either of limestone

or of other iron ores high in the bases. The Clinton ores of Alabama are of this type and except for the unfortunate percentages of phosphorus which they might add to Lake Superior ores, they would doubtless make an advantageous mixture with the latter. But the southern ores are remote from the northern. In order to meet them at or near the supplies of fuel a long railway haul would be necessary. While this is not impossible, it would add to the cost so greatly as to be highly improbable. There is one further consideration. The greater part of our pig iron is used in the manufacture of steel. For this purpose in the two processes most extensively employed hitherto, we need, respectively, either a very low or a fairly high percentage of phosphorus. If our irons are in between, and like the church at Laodicea, neither hot nor cold, they have been ill-adapted to steel manufacture. Unless the growth of the open-hearth process introduces great changes, the mixture, therefore, of southern basic ores and northern siliceous ones is not altogether promising for this reason.

The greatest cause of apprehension as regards present processes of iron manufacture lies in the supply of coking coal. We have built lofty furnaces, and in their use we place upon the fuel as it progresses downward in the furnace a heavy load of overlying ore and limestone. We need a very strong coke to stand up under the burden. The coals which yield these high-grade cokes are found in a small portion of the total coal-bearing area, and the life of the supply is one of the very serious phases of the present situation. I do not know what the amount of reserves may be.

While these physical and chemical factors operate to increase costs, there is always the possibility of improved processes and of greater efficiency to keep them down. The improvement oftenest in people's minds to-day is the utilization of water powers to generate electricity, which in turn may supply heat. Now, in a blast furnace smelting iron ores, one third the fuel is employed in reducing the iron oxide and two thirds in developing the necessary heat for the reaction. Were we able with water powers to economically furnish electricity and from it derive the necessary heat we might save the two thirds of the present amount of required fuel. We might reduce costs. The remaining one third of the fuel we should always need but it is possible that poorer grades than high quality coke might answer. The saving would lie, of course, in the difference between the cost of the fuel and the cost of the electric current, provided the latter could be furnished more cheaply than the former.

The water powers in our own country or at least in the more thickly settled portions of it, have not failed to attract attention, nor have they gone altogether unutilized. The more conveniently situated ones are already harnessed to the dynamos. But in countries like Norway and Sweden, where there are large water powers still available, where there are rich deposits of ore and where coal fails, the applications of electricity to iron smelting are likely to be first worked out successfully. Data may be furnished in the life-time of many of us, which will cast light upon these improvements in their world-wide relations.

The only other apparent possibility of reducing costs lies in the labor charges. Wages at present are not unduly high, and unless the increasing population of the country brings to pass an inevitable struggle for existence, which will cause the greater subdivision of tasks at lower proportionate returns or unless the general reduction of expenses for subsistence makes lower wages possible, there would seem to

be slight prospect of change in this item. In any event the reductions from this cause can not compensate the falling off in the yield of iron as foretold above.

Suppose iron goes up in cost—other conditions of our daily life remaining the same—transportation and all manufacturing based on machinery would become more expensive; and less freely carried on. Undoubtedly an appreciable pressure would be developed to turn our people back to the rural districts and to tilling the soil for a livelihood. The tendency under the stimulus of manufacturing development has been the other way. The migration of late years has been toward, not from the cities. Shall we perhaps find in the long run, in the increasing cost of iron and steel a partial solution of a much vexed problem? Will the cry "back to the soil" receive support in a way not generally anticipated? The question is an interesting one for speculation.

The general inference regarding copper is that the pinch of higher cost of production will be felt sooner than in the case of iron. We have no knowledge of such enduring reserves of copper ores as we have of iron. On the other hand, copper, despite its vast importance, is not the fundamental necessity that is iron. It is used in less quantity in machinery and its increase in cost would less vitally affect manufacturing industries based on machinery. Advancing cost would cut it out of much ornamental work of inferior esthetic merit. The most serious effect would be found in raising the expenses of service in the applications of electricity. Electrical transportation, telegraphy and telephony would be more expensive than to-day. Unless wireless methods of transmission eliminate copper, or unless some discovery in the domain of physics which we do not now foresee furnishes a substitute for the omnipresent copper wire of to-day, we may find ourselves face to face with some curtailment in these modern aids to the easy conduct of life's affairs. If in the course of several centuries the falling off in supply and the growth in population should raise copper to relatively high figures, we may wonder if a return in a way to the conditions of the middle ages will not result. Will copper then become to a greater degree than now the basis of skilled handiwork? Will the by-gone craftsmanship be revived and with a lessening total output shall we see an advance in artistic skill? In fact, if the vast development of machinery and the huge output of metallic objects at low cost—a condition so characteristic of to-day—should be checked or curtailed, would not hand-work on more valuable mediums of expression be restored. It is not altogether unreasonable to anticipate fewer objects and higher crafts in their production.

The cases of lead and zinc are even more emphatic than that of copper. We have still fewer assured reserves and the pinch of increasing cost may manifest itself at an earlier date. The two metals are not, however, quite such vital factors in modern life as is copper and the larger effects would be less apparent. Zinc is a necessary component in the manufacture of brass, which industry absorbs the greater part of the copper output. A curtailment of either lead or zinc would cause inconvenience, but would scarcely occasion fundamental changes.

Silver will be very seriously affected by a decrease in the output of either copper or lead. Gold will feel these changes in an appreciable but far less degree. There will always be sufficient, however, of each of the precious metals for coinage, and beyond this use their applications, except perhaps in photography, concern luxuries rather

than fundamental necessities. We can not attribute to them any profound possibilities in their influence upon civilization should the contributions of the mines decline. In the recent past we have been more apprehensive regarding a too great supply of the precious metals, than regarding one too small.

With the increasing interest in the discussions of the conservation of natural resources, there has been an increasing disposition of the authorities to assume supervisory powers over mining and metallurgical operations. The old-time idea that to the crown, or, as we are accustomed to say, to the state, belongs the mineral wealth of the earth, is experiencing something of a revival. The disposition to restrict the waste of valuable metals or minerals in processes of manufacture is commendable and after careful demonstration that it is feasible and just to the operating concerns, it may be wisely done. The rejected product of concentrating mills or the "tailings" so called, when provided with appreciable percentages of metals, may well be stored where they can be utilized by future generations, if processes improve so as to make them available. That is to say, they should not be run into rivers, or placed where they will be dissipated. The same remark applies to slags from metallurgical works. The moderns, for example, are now working over the lead-bearing slags left by the ancients at the great lead mines of Laurium, Greece. Even the slags of early smelters in the west and Mexico may again pass through the furnace.

Another question relates to the discovery, location and ownership of mining property. So far as the metals are involved, and with the metals this address has been alone concerned, the valuable discoveries are so few in comparison with the disappointing attempts to develop, that only by encouragement and rather generous conditions will the prospector be enabled to follow his arduous calling. He must be offered large prizes proportionate to the many failures. He must be assured of possession by a very circumspect and conscientious administration, if confidence in the justice of the government is to be maintained. People in the parts of the country where mining for the metals is not carried on hear only of the great successes and little of the innumerable disappointments. Far the largest part of the population thus acquire very distorted views of the real conditions of mining. The interference by the government other than in the ways which I have mentioned and in maintaining reasonably safe conditions for the workman, is a matter to be regarded with great caution, lest irreparable injury be done to the large problem of maintaining our future supplies with such new discoveries and developments as may be feasible. The wisest course is to improve the method of establishing and recording titles to new discoveries, and then, except in the matters already mentioned, to let the natural course of business assert itself. The proper share of the state will be obtained through the normal processes of taxation.

The mines for the metals do not, however, present the most important phase of this subject. Coal is a more serious problem, and one demanding more extended treatment than would be justifiable in an address primarily devoted to other themes. One may only express the hope that where cases of dispute arise they may be determined in the courts, according to the established rules of evidence.

The resources in the metals which have been found in the United States have proved so great as to make the industries based upon them a very vital factor in our

whole civilization. Great changes in the supply or the cost will inevitably react in the long run upon the opportunities for employment and support, and upon the very nature of our national life. While it will be a long time before rearrangements in the case of the most important of the metals, iron, will be manifest, and while they will assert themselves gradually, we are quite certain to face new conditions in copper, lead and zinc at an earlier date. In the end, however, we can perhaps justifiably forecast a future in which agriculture will figure more and more prominently and in which the moral, intellectual and spiritual life of the nation will readjust itself accordingly. Great and concentrated wealth is likely to be less in evidence, materialistic influences less pronounced, and from the vantage ground afforded by the greater comforts and opportunities of modern life as compared with that of a century or a half century past, we may in the distant future look forward to an evolution upon somewhat different lines. Broadly viewed, the national life will probably be increasingly sympathetic with art and with ideals.

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CITY SANITATION[1]

Great cities have grown and passed out of existence. The enormous increase in urban population in very recent years has produced even greater cities, which may also in time cease to be. In fact, aside from the possibility of local or cosmic calamity, this is sure to occur, unless due attention is given to the application of the principles of chemistry in our daily, personal and communal life. London, Paris, Bombay, Rome and New Orleans have had their scourges in the past to testify to the fearful penalty of ignorance and neglect.

Indications point to an urban growth and development, the conception of which taxes the imagination. When we see New York as it was two hundred years ago, and then one hundred years ago, and as it is now, we may well wonder what it may be fifty years from now. The annual increase in population is about 300,000. It has been calculated that in 1920 New York may have 7,000,000 of people.

It has been predicted by a close and conservative student of sociology that two generations may see the eastern part of our country mainly composed of contiguous cities. In 1790, 3.3 per cent. of the population of the United States was urban. It was 33.1 per cent. in 1900. The problems of the state and county become closely interwoven with those of the city. The city will no longer be merely an accumulation of human beings in a particular locality, with its local problems and influencing the state mainly in a financial way, but the city will have become the state.

The individual needs fresh air, pure water, good food, safe shelter, and should have a clean body and something beautiful to look at. When he associates himself into a city his needs are not lessened, but emphasized. The growth of a city causes it to assume, willingly or no, corresponding obligations. The inhabitants must breathe, they must be fed and watered, its wastes must be got rid of, facilities for the safe coming and going of its people at all times must be provided, as well as protection from fire or other adventitious circumstances which concern the welfare of the citizens. The needs thus simply stated are to be met by obligations which become more and more complex with the increase in population. In fact, most of the city's problems are of comparatively recent date.

[1] An address at the tenth Conference of the Health Officers of the State of New York, Buffalo, N. Y., November 17, 1910.